

A review of world-wide requirements for fire-resistant conveyor belting†

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Abstract: The requirement for fire resistant conveyor belting is examined in its historical context. The paper reviews the subsequent development of standards for fire resistant conveyor belting internationally with an assessment of the most recent work.

1 Introduction

Those already concerned with belt conveying and mining will already be aware of the fundamental effect that the development of standards for fire resistant conveyor belting has had on safety in underground mining. What may have been forgotten, however, are the historical events leading up to their introduction which need to be reviewed in order to put the later developments into their true perspective.

In 1948, there were 842 miles of conveyors in use underground but by this time also there was an increasing awareness of the danger from fire rising from their use. In 1947, HM Chief Inspector of Mines and Quarries, in his annual report¹ recognised the seriousness of the situation and gave a detailed consideration of the hazards associated with belt conveyors one of which was:

Fires on conveyors have occurred with alarming frequency in recent years, no fewer than 63 having been reported during the past seven years. Amongst the causes of these fires, 29 were attributable to frictional heating.

In his report,² the Chief Inspector stated that the fact that no fewer than 15 conveyor fires occurred during 1948 showed that this menace was assuming alarming proportions and demanded immediate attention.

One of these fires, on 9 December 1948, occurred at an unattended gate belt conveyor at the Chatterley Whitfield Colliery in North Staffordshire in which three men lost their lives. The fire was later attributed to torn belting and frictional heat and was one of many similar occurrences. The later horrendous disaster at Creswell had virtually been predicted.

2 Early investigational work

The danger arising from the build-up of frictional heat, mainly in idlers, had been recognised in the later 1930s in Germany, but following the fire at the Whitfield Colliery in 1948, the National Coal Board (NCB) undertook their first significant investigation in conjunction with the Safety in Mines Research Establishment (SMRE) into the generation of fire in conveying.

At about the same time, an investigation³ was also carried out in Holland by Dr W. Maas of the Netherlands State Mines but with a different conclusion. Dr Maas constructed an experimental rig, see Fig. 1, incorporating a rubber lagged drum with a rubber and canvas conveyor belt which could be held stationary using a clamp and chain. When the driving drum was rotated, the temperature rapidly rose, leading initially to the rubber softening and the forming of small rolls of rubber which collected at the point where the belt left the drum. When the canvas became exposed, strips became detached which, in an air current, broke into flames. Maas finally concluded that, because of the time element before the canvas was exposed, the fire hazard was less the thicker the rubber cover, the lower the tension and the lower the air speed. The recommendations following this report were more concerned with the efficient mechanical operation of the conveyor rather than the development of fire-resistant belting.

The NCB/SMRE team reconstructed the actual drive head involved in the fire at the Whitfield Colliery and set up a similar conveyor, see Fig. 2. Following several experiments with thermocouples embedded in the belt, they installed a piece of the actual belt from the pit and proved conclusively that the fire had been caused by frictional heat. Coal dust from the pit was spread on to the belt and around on the floor and the drive set in motion with the belt stationary. This belt broke in 20 min. The

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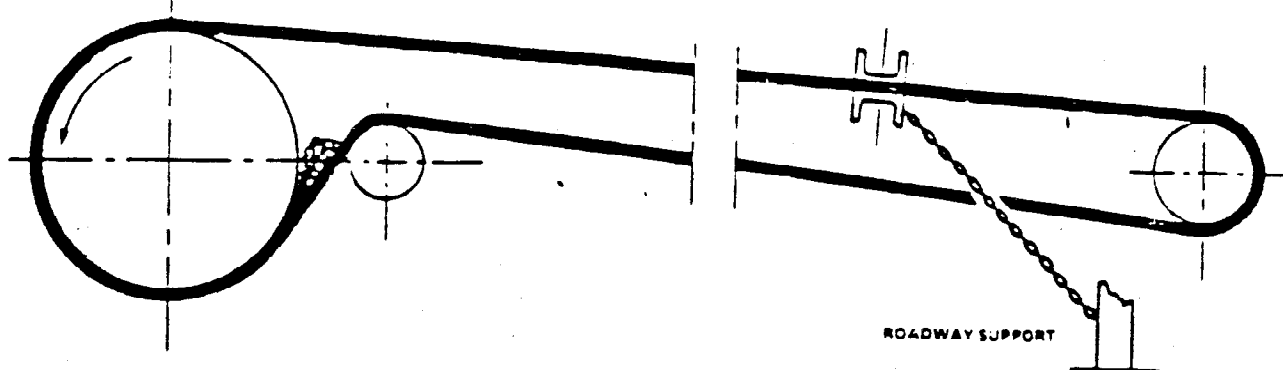


Fig. 1 Maas investigation. General arrangement of the conveyor belt test installation.

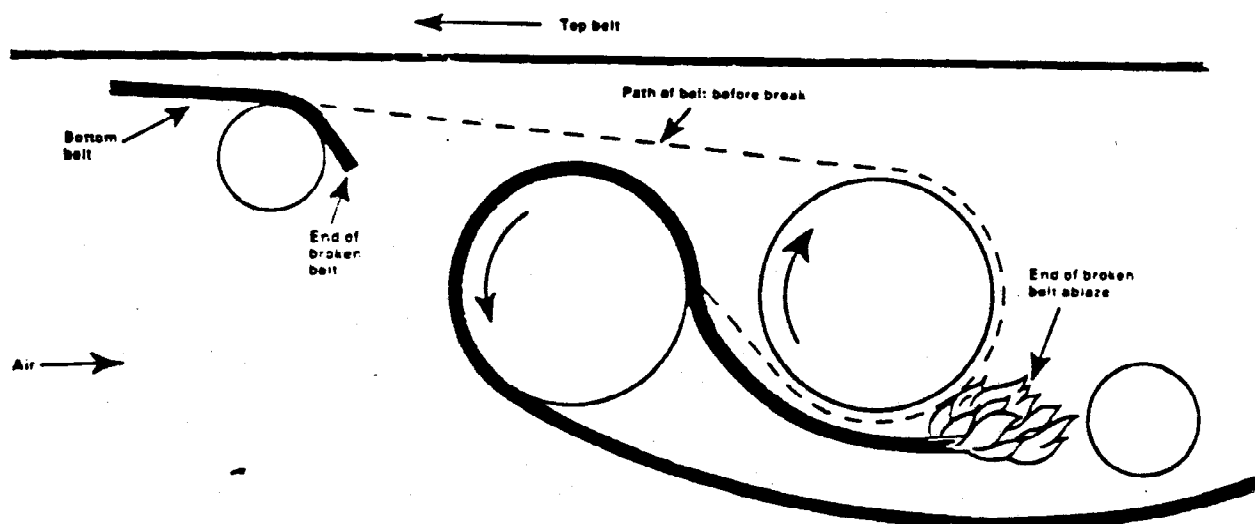


Fig. 2 Whitfield Colliery investigation. Burning belt after break.

broken end of the belt fell glowing into the coal dust and within 10 min was well alight. There was no doubt that this was how the fire had started at the Whitfield Colliery. Improved maintenance or an increase in cover thickness as concluded by Maas was not going to be sufficient to cope with the situation. Before this work was finalised, however, the now infamous disaster at Creswell Colliery occurred.

2.1 Creswell Colliery disaster

On 26 September 1950, a disastrous fire started at the No. 2 transfer point and, although the wooden props and lagging caught fire, the conveyor belt was responsible for spreading the fire rapidly. At the time of the fire, there were 232 persons underground. 131 were in the district of the fire, 51 of whom escaped. The remaining 80 perished as a result of carbon monoxide poisoning.

Subsequent investigations showed that torn belting had jammed between the delivery chute and the moving belt of the No. 2 transfer point and that this had been pressed tightly against the moving belt of the delivery drum, see Fig. 3. The frictional heat

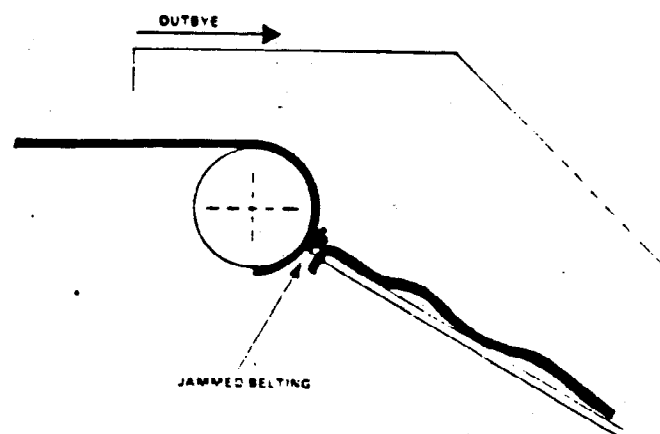


Fig. 3 Creswell Colliery. Diagrammatic arrangement of No. 2 transfer point.

developed at this point had then initiated the fire. Note, this was not friction between the belt and the driving drum.

The Minister of Fuel and Power ordered a Statutory Public Enquiry into the disaster and instructed HM Inspector Sir Andrew Bryan to preside and furnish a report⁴ which was presented to Parliament in April 1952, the delay being occasioned by

the inability to open up the district until some considerable time after the fire had occurred. One of the 21 recommendations of the subsequent report following the Public Enquiry was, 'as soon as they are proven in practice and are commercially available, only belts which are non-inflammable or are highly resistant to fire should be used'.

2.2 Investigation by NCB

Within days of the fire, the NCB set up an investigation and research team under Mr J. T. Barclay.⁵ The first step was to analyse the fires on underground conveyors in British Coal Mines for the previous ten years, which clearly indicated friction as being the major source of fire generation. Fire propagation was considered secondary. This point is fundamental and is the basic reason for a major difference of opinion concerning standards of fire resistance between the UK and many other coal mining countries of the world.

Two sources of frictional heat were considered:

- (a) A moving belt against a fixed surface; here it was quickly concluded that it would be extremely unlikely that a belt could be ignited in this manner.
- (b) A stationary belt against a rotating drum – the stalling condition.

To investigate the stalling condition, an apparatus was set up incorporating an 8 inch diameter drum with variable speed gears driven by an electric motor. Tension was measured by a statimeter and temperature measurement was by thermocouples and surface pyrometers. Various speeds of the drum and widths of belting were tried before finally deciding on a speed of 190 rev/min together with a width of 6 inches.

100 belt samples, mostly cotton, were tested and provided that the samples were greater than 3 inches in width, ignition occurred on every occasion, in a similar manner to that in the Whitfield experiments. From these tests they concluded that the greater the tension and the wider the belt, the more quickly a fire developed.

Following this work, the conclusions were reached that not only would the duck have to be fire resistant, which appeared to be the major problem, but the belt as a whole would also have to be fire resistant. It was also concluded at this stage that two tests would be necessary adequately to ensure that the belts would fulfil two main criteria:

- (a) The belt must not be capable of ignition by friction, but in addition,
- (b) the belt must not propagate or intensify an external fire with which it may be brought into contact.

This stage was reached only six months after Creswell, which shows the intense concentration of effort in

what was now an entirely new field of conveyor belt testing and development.

The UK conveyor belt manufacturers were then asked to submit belts for trial purposes. At the same time, the NCB refined the test methods which would be used to assess fire resistance. By mid-1952, belts were available which fulfilled the fire resistant requirements although further development would be needed for optimum performance.

During this period, the drum friction test conditions were finalised with a belt end load of 70 lbs. The test was to be carried out in both still air and in an air current with a velocity of 500 fpm to simulate forced ventilation underground, see Fig. 4.

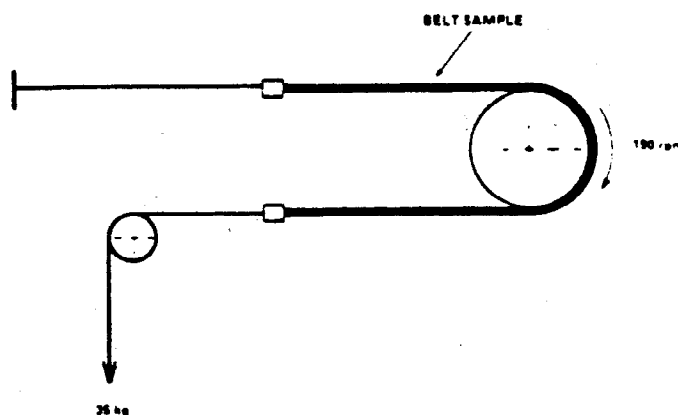


Fig. 4 NCB drum friction test, diagrammatic arrangement.

It was realised very early in the work that whilst the belt was still intact around the drum, power was being absorbed and frictional heat generated. Once the belt parted the source of the heat was removed leading to the conditions of acceptance that:

- (a) The test shall be continued until the belt has parted.
- (b) There shall be no sign of flame or glow at any time during the test and the drum temperature must not exceed 300°C.

These conditions of acceptance have since proved most controversial world-wide.

The drum temperature requirement of 300°C was introduced because of certain belts which, although they did not ignite under test, gave rise to excessive drum temperatures. Coal dust sprinkled on such belts during the test ignited when the temperature of the drum below reached 300°C. It should be remembered that this test is simply a means of assessing the performance of a belt under the effect of friction. It is not the only source of frictional heat as instanced by the Creswell conditions.

To ensure that the belting would not intensify or propagate a fire, an investigation involving large scale gallery trials and radiant panel tests was carried out, culminating in the now familiar Barthel Flame Test (later to be called the Spirit Burner Test) (see

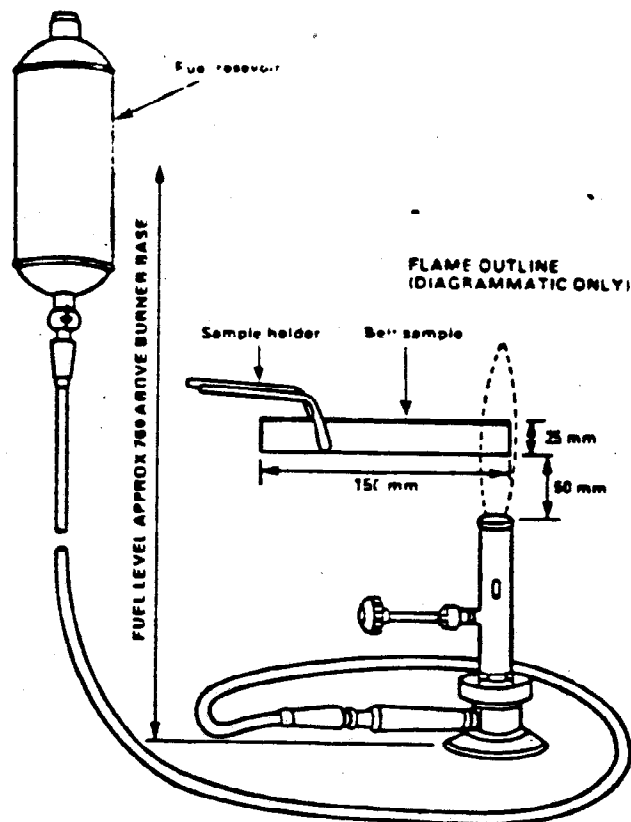


Fig. 5 Barthel burner test for determining fire resistance of samples of conveyor belting (all dimensions are in millimetres).

Fig. 5). The test at that time consisted of six pieces cut from the belt, each 1 inch wide by 12 inches long, three in the warp and three in the weft direction, to be tested with the covers intact. A similar set was prepared with the covers removed to simulate worn belting. Each test piece is held in turn horizontally in the flame of a Barthel spirit type burner for 30 s with the lower edge of the piece 2 inches above the burner. The burner is then withdrawn and the time to extinction of all flame and glow is measured, the test being carried out in a draught free cabinet.

The conditions of acceptance were:

1. For the six test pieces with the covers intact, the average time for all visible flame or glow to disappear after the withdrawal of the burner shall not exceed 3 s.
2. For the six test pieces with the covers removed, the average time for all visible flame or glow to disappear after the withdrawal of the burner shall not exceed 5 s.

The choice of 1 inch wide test pieces followed correlation tests with full width samples of belting and was found to give the most reproducible results. Wider test pieces were found to be unnecessary whilst $\frac{1}{2}$ inch wide test pieces gave inconsistent results.

The two tests were developed and finalised during 1951 and 1952 and the UK manufacturers were

generally working in accordance with them from that time onwards. The tests were finally incorporated in a National Coal Board Specification P113/1954, *Fire resistant properties and marking of conveyor belting*.⁶ It was the first standard of its kind in the world and is probably the most important landmark in the field of conveyor belt safety. The tests were also incorporated in BS3289, 1960, *Conveyor belting for underground use in coal mines*.⁷

Later amendments to the specification included anti-static requirements and the full range of physical properties including a tear requirement which together with the introduction of synthetic yarns minimised the last major cause of frictional heating, arising from torn belting. Also, to more closely simulate field conditions, the end load in the drum friction test was increased incrementally over a period of 2 h 10 min to 350 lbs.

The drum friction and flame tests have remained basically unchanged since their introduction but the NCB Specification, now numbered 158,⁸ has been completely revised to include more detailed physical requirements and also requirements in accordance with EEC Mines Safety and Health Commission regulations which will be referred to later.

In addition to the specification, and almost as important, was the introduction of the National Inspection of Colliery Equipment (NICE) Scheme in 1957, now incorporated generally in the NCB Quality Assurance Schemes^{9,10} and supported by a formal approval procedure,¹¹ involving belting acceptance tests and manufacturers' deposited specifications, which together ensure that the belting supplied continues to meet the very high standards of safety, in a comprehensive system still unique throughout the world.

2.3 Effect of the NCB specification

The effect of this specification was probably best summarised by HM Chief Inspector in his 1961 report,¹² where he stated 'the development of fire resistant belting has proved a rich blessing to the industry'. What a change from the 1947 and 1948 reports!

2.4 The situation in America

Following the NCB investigation, similar work was carried out in many of the major mining countries over the next few years. In the USA, an investigation in 1954, by the United States Bureau of Mines (USBM), showed that 50 fires associated with conveyor belting had occurred over a period of a few years, some associated with the loss of life. Although the Federal Mines Safety Code referred to fire resistant conveyor belts for underground use, there was no method of assessment so the regulation was ineffective.

The Director of the USBM presided at a meeting of all interested bodies in July 1954 and appointed a research committee under S. Pollack, which examined spontaneous combustion (which proved inconclusive), flame testing, friction at the drum and fume emission. The committee introduced a flame test,¹³ see Fig. 6, based on an earlier ASTM test, involving a 21 inch cube cabinet with a carefully specified ventilation system. A Pittsburgh burner was mounted below a wire gauze in the cabinet and generated a flame temperature of about 750°C. After testing 500 specimens from 90 sample belts manufactured in the US, UK, France and Germany, the conditions were finalised.

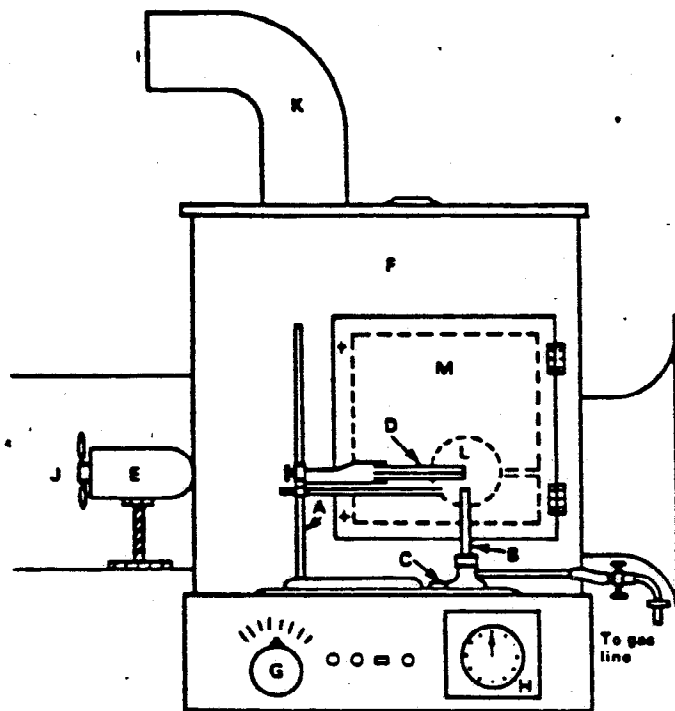


Fig. 6 Schematic diagram of flame-test apparatus. A, Stand; B, bunsen burner; C, burner stop; D, test place; E, exhaust fan; F, 500 mm cabinet test gallery; G, fan switch; H, timer; J, draft inlet; K, vent; L, inspection mirror; M, glass inspection opening.

Four $\frac{1}{2}$ inch wide samples are each held in the flame for 1 min in still air. The burner is then removed and a 300 ft/min current of air is passed over the specimen for at least 3 min after the flame has been extinguished. The average time for the extinction of all flame must be no greater than 1 min and of the after glow, 3 min. These conditions are far less severe than the NCB. It is interesting to note the choice of a test piece width of $\frac{1}{2}$ inch which conflicts with the conclusion by the NCB that widths below 1 inch gave variable results.

The study of the reaction of conveyor belts to friction followed a similar pattern to the NCB, but using an 18 inch diameter drum operating at 110 rev/min and a 9 inch wide belt held under tension by a direct weight of 50 lbs, increased over a period

of 2 h to 270 lbs. In other respects, however, the approach was entirely different from that of the NCB.

It was found with chloroprene belts, once a temperature of 180–220°C was reached, it remained constant at the tensions used. (This conflicts with more recent work in Germany where temperatures in excess of 500°C have been obtained with similar belts.) Because of the apparent state of equilibrium with such a low end load, the test was considered complete at the end of 2 h if the belt was still intact and the temperature inside the belt measured by thermocouples had not exceeded 250°C. The situation concerning PVC belts was considered inconclusive by the USBM in that they were destroyed without flame or glow before the 2 h were complete. This was entirely contrary to the NCB conclusion that the belt must part.

The flame and drum friction tests were combined into a standard which was legally constituted as Schedule 28, now Schedule 2G, of the *Code of Federal Regulations*, Title 30, Mineral Resources, on 9 November 1955. Following the Federal Coal Mines Health & Safety Act of 1969, the *Code of Federal Regulations* did not incorporate the drum friction test and currently only the flame test is recognised in the USA.

2.5 The situation in Holland and Belgium

Other important early work in this field was by Dr Maas¹⁴ in Holland who, in addition to his work with a stalled drum, carried out a fundamental programme leading to the development of a large scale gallery test, which was subsequently adopted also by Belgium. The test will be described later in relation to more recent work. Both Holland and Belgium also adopted what was basically the NCB drum friction test but with modifications involving coal dust.

2.6 The International Standards Organisation

The International Standards Organisation (ISO) also considered the overall question of fire resistance and issued recommendation R340, *Flame resistance of conveyor belts* in September 1963, based on the Barthel Burner applied at an angle of 45° to the sample, see Fig. 7. It was optional whether the test should be carried out with the covers removed. The question of a drum friction test was discussed, but was never finalised.

3 Stabilisation period

There then followed a stabilisation period of about 10 years with no significant change in any of the standards referred to. Throughout the world, the mining communities compiled standards to suit their own requirements which were based on the NCB,

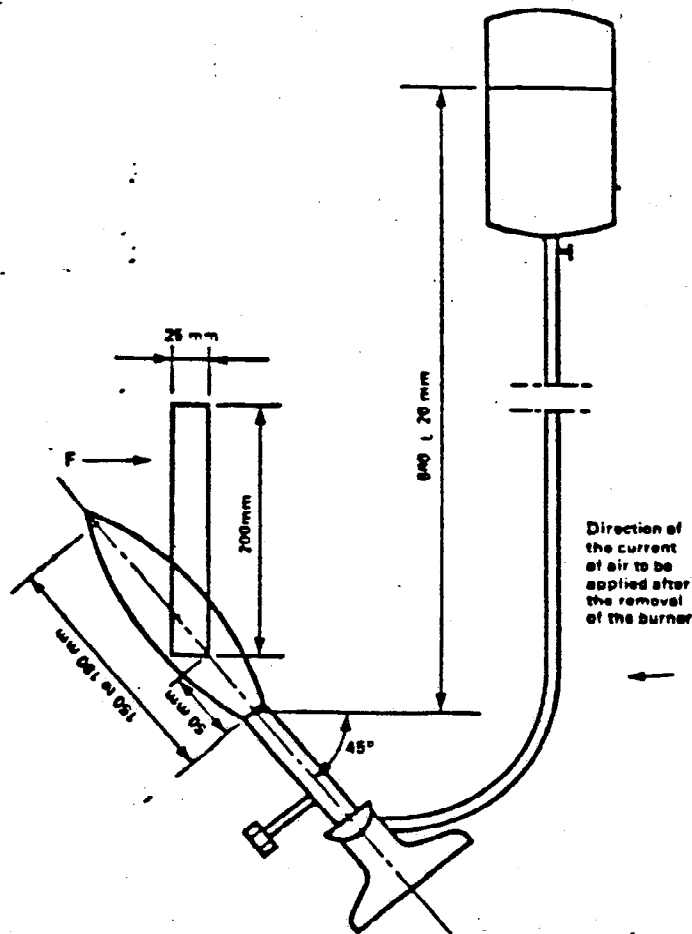


Fig 7 ISO recommendation R340, Flame resistance of conveyor belts.

the USBM or the ISO tests, or with parts of each as appropriate. Only Holland and Belgium retained the gallery test.

For example, the Canadian specification was based on the USBM flame test but with a still air

condition, making it more severe, supported by a drum friction test based on the corresponding NCB test. Other countries incorporating these tests into their standards were India, Australia and South Africa. France and Germany had flame tests of a similar type but no drum friction test. Poland, Rumania and Czechoslovakia also introduced standards based on variations of the same tests.

4 Re-appraisal

4.1 The situation in Germany

The period of stabilisation could be said to have ended with three extensive fires in German coal mines in the late 1960s and early 1970s which led to investigations into the effect of large scale gallery fires.

The Germans have now generally finalised their work which involved the use of two separate galleries, one full scale (see Fig. 8), and one laboratory scale (see Fig. 9). The full size 'Grossbrand' gallery is constructed underground with automatic monitoring both underground and on the surface. Eighteen metres of belting are used in the test, the sources of ignition being 300 kg of wood. The condition of acceptance is that the flame must not spread more than 10 m from the fire zone.

The laboratory gallery is 2.1 m long and 35 cm square constructed from 25 mm thick asbestos with an observation window on one side. The source of ignition is a small propane burner. The sample is 1200 mm long and 90 mm wide and is mounted 85 mm below the top of the cabinet. The burner is placed under the end of the sample for 15 min with an air current of 0.5 ± 0.1 m/s through the cabinet, the condition of acceptance being that the average

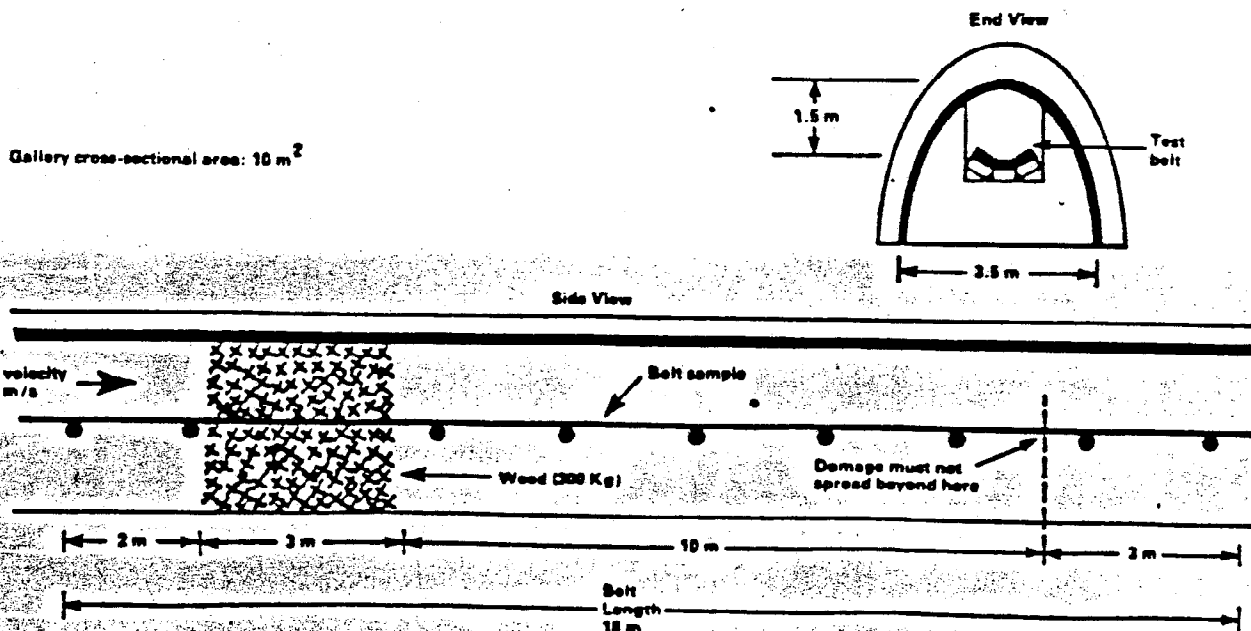


Fig 8 Testing for flame spread at the full-scale experimental mine, Tremonia, West Germany.

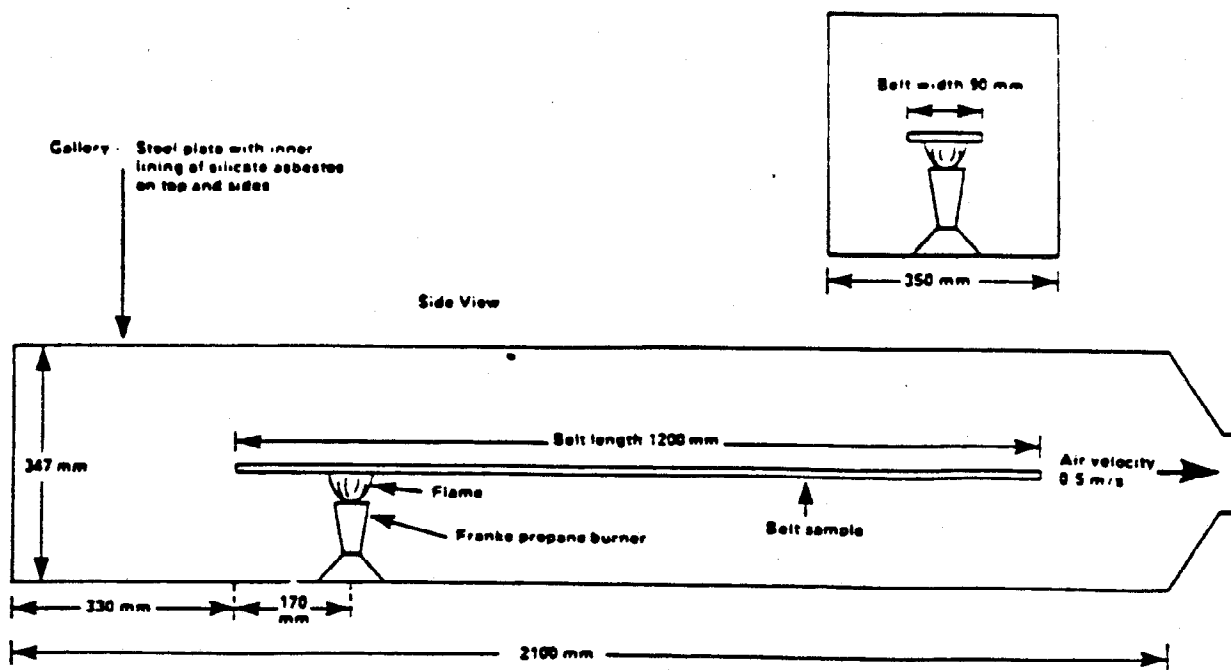


Fig. 9 German laboratory gallery test for flame spread, DIN 22118.

length unburnt for five samples shall not be less than 40 cm.

These tests are included in the draft German Standard DIN.22118.¹⁵ The draft standard was submitted to the ISO and the European Mines Safety and Health Commission and although not accepted, has had a significant effect on the later development of standards for fire resistant conveyor belting.

4.2 Mines Safety and Health Commission

Within the EEC, the Mines Safety and Health Commission, with jurisdiction over the whole of the Common Market Mining Industry, also investigated the fire resistance of conveyor belting in parallel with the work in Germany. After considerable investigation, they have introduced the gallery test¹⁶ developed by Dr Maas in Holland, together with a drum friction test¹⁶ basically the same as that of the NCB but with the conditions of acceptance determined by each individual country, e.g. Germany allows 500°C at the drum, France 450°C, whilst the NCB now requires 325°C based on a more accurate method of temperature measurement.

The gallery test, see Fig. 10, now generally known as the propane test, uses a 450 mm square burner frame incorporating 52 jets, each 1.5 mm in diameter, fed with 1.3 kg of propane over a period of 10 min. The burner is placed under one end of a full width sample of belting 2 m long, supported on a metal framework in a gallery of 2 m x 2 m cross section, with an air current of 1.5 m/s. The condition of acceptance is that after turning off the burner and after the extinction of all flame and glow, there shall

remain a part of the sample intact over its whole width.

This test became mandatory throughout the EEC with the result that in the UK the NCB Specification continued to apply but with the addition of the propane gallery test, but with a stiffer acceptance level requiring 250 mm unburnt. In Germany, the EEC standard also applies, but in addition they carry out the requirements of DIN.22118. In France, the EEC standard is supplemented by what is basically the ISO flame test.

4.3 More recent work in the UK

As part of the overall investigation into improved standards of safety in Europe, the NCB, in close liaison with the UK conveyor belting manufacturers, carried out a critical review of Specification 158. The propane gallery test has already been referred to, but the Barthel Flame Test was more carefully specified to improve reproducibility both in the operation of the burner and the manner in which the flame test cabinet was constructed. The total number of test pieces was increased from 12 to 24. The already very low average times to extinction were left unchanged at 3 and 5 s, but upper maxima for any one result in the covers on and covers off condition have been set at 10 and 15 s respectively. Overall, the test is now, therefore, even more severe.

Following an investigation into the fire resistance of steel cord belting, particularly the difficulty in achieving ignition, the NCB have introduced an extended propane gallery test. The gallery, burner

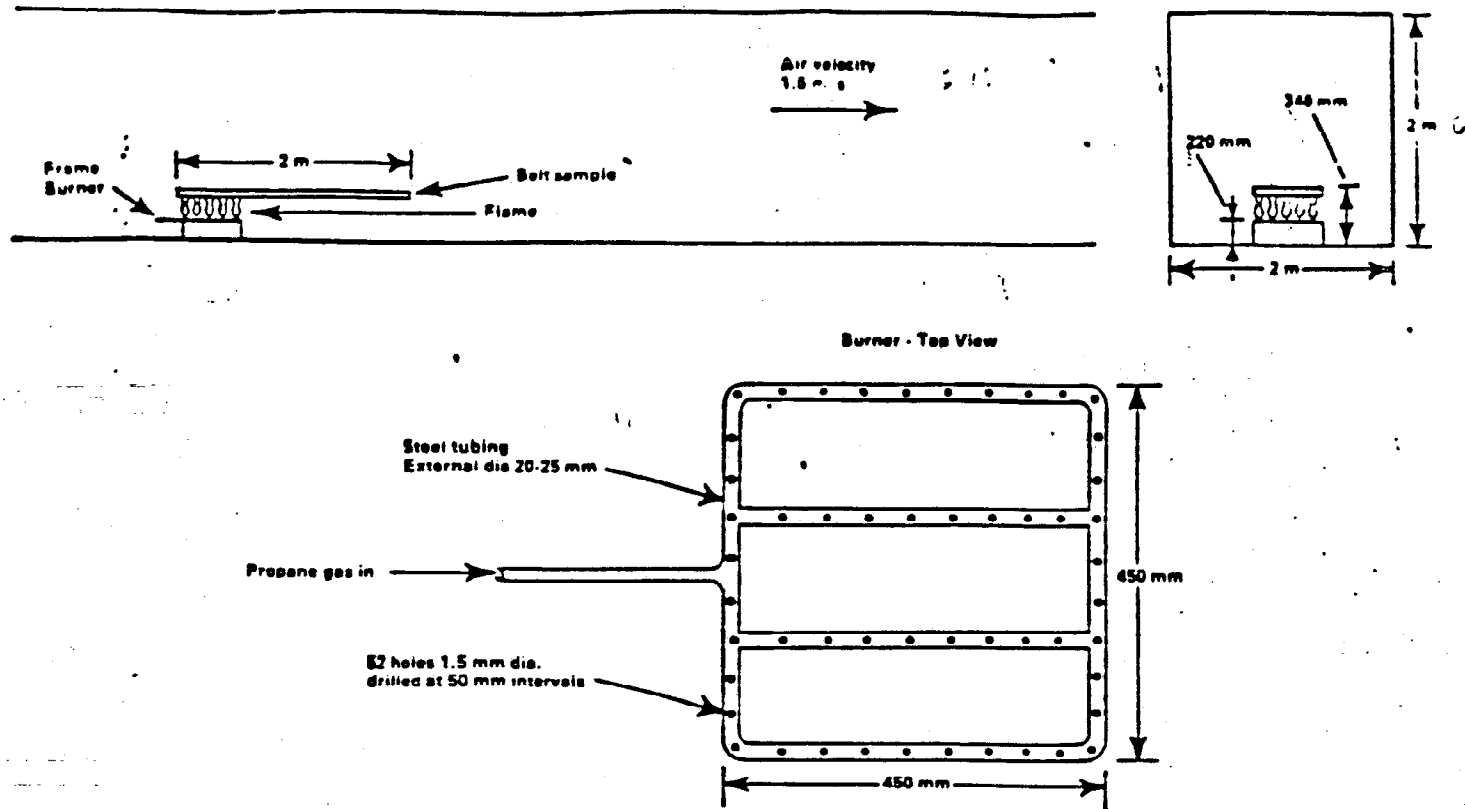


Fig. 10 EEC propane gallery flame test.

and airspeed are unchanged but the sample length is increased to 4 m and the flame is applied for 50 min with an increased flow of fuel. This test supplements the previously described 2 m propane gallery test and is used, mainly, for high tensile belts or belts of entirely new construction.

These latest UK tests for fire resistance have been developed by the NCB for inclusion in Specification 158/1980 but they are also incorporated in the recently published BS 3289, *Conveyor belting primarily for use underground (including fire performance)*¹⁷ and this British Standard is the culmination of almost ten years of work in close liaison between the NCB, manufacturers and major users.

5 Second stabilisation period

Following the period of tremendous activity in Europe, we are now entering what will be a second period of stabilisation where countries throughout the world are re-examining their own standards, based on the most recent work.

The New South Wales Department of Mines in Australia, has retained their USBM type flame test and the NCB type drum friction test, each with stiffened conditions of acceptance, but have in addition now included the propane gallery test.

Canada are carefully reconsidering their standard¹⁸ and for explosive atmospheres are closely following the Australian approach with more severe conditions of acceptance for their USBM type flame test and

NCB drum friction test, together with a propane gallery test although the details have to be finalised.

Gallery testing has thus gained acceptance throughout the majority of the major coal mining countries of the world including Poland,¹⁹ where they have introduced a test similar to the German Grossbrand and the EEC propane test. India and South Africa are the exceptions where so far there has been no move to either increase the severity or introduce a gallery test.

5.1 Current situation in the USA

The situation in the United States is interesting in that the USBM has carried out a fundamental investigation²⁰ into laboratory gallery testing, whereas the Mines Safety and Health Administration consider that the existing Schedule 2G flame test is entirely satisfactory.

The insurance companies in the US are now taking an increasing interest in conveyor fires, particularly in the grain industry, and they will probably have the most influential effect in the long run.

5.2 Continuous testing for fire resistance

Following the Schlagel and Eisen fire in Germany,²¹ despite the general introduction of gallery flame testing in Europe, all members of the European Mines Safety and Health Commission in close liaison with the coal industries and belting manufacturers

throughout the EEC collaborated in a major programme to ensure that belting, once approved, continued to be fire resistant – a policy that the NCB/NICE scheme preceded by more than 20 years.

Two tests were considered: the Barthel burner (now known as the spirit burner) test and the Limiting Oxygen Index (LOI) test, also sometimes known as the Critical Oxygen Index (COI) test.²² The Barthel burner test has already been described.

In the LOI test, a sample of belting is burnt in an atmosphere of nitrogen into which a known proportion of oxygen has been introduced. Although the test is highly reproducible for a homogeneous material, it is not so with a composite such as a conveyor belt and the UK remains in favour of the spirit burner test. Other countries were not quite as decisive and in two reports²³ issued together by the Mines Safety and Health Commission it is stated that there should be a test for continuous quality control testing for fire resistance, but either the spirit burner or LOI test may be used. The LOI test is accepted in Germany where it is part of that country's approval procedure. The test is also under review in Canada and Australia.

6 Final comment

Although there is a difference of opinion concerning the LOI, a new trend in safety standards is becoming apparent, i.e. trying to ensure that all belts continue to meet the original acceptance standard. In effect, we have turned full circle.

The spirit burner test, developed more than 30 years ago, rapidly assumed a role as a quality control test for fire resistance once the drum friction requirement was introduced and this aspect above all else has probably been one of the major reasons for the absence of conveyor fires in British coal mines over the past 30 years.

The development of QC systems rather than actual tests is opening up the next field of standardisation.

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